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ABSTRACT

Four experiments investigated the phenomenon of letter migration, the tendency of readers to assign letters from one word to another appearing in close proximity. The experiments, which involved college undergraduate students, revealed several properties of letter migration, including the following: (1) migrations are more frequent when the words are separated by small physical distances; (2) a majority of the migrations are a result of letters being copied from one word to another, not from the interchange of letters of the two words; (3) migrations to a word are less frequent when subjects focus attention on that word; and (4) migrations are far more frequent when the words share letters in common. This last result suggests that migrations are not caused by a loss of spatial information at the letter level, that is, by free-floating letters being wrongly combined. Rather, migrations occur because of structural limitations at a high level of the word recognition process, perhaps during lexical activation. (Author/FL)

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Abstract

These experiments demonstrate that the perception of two distinct words in a briefly presented display can interact, causing perceptual migrations of letters from one word to the other. For example, when LINE and LACE are presented, subjects might report seeing LICE or LANE instead of LINE. Several properties of the letter migrations were revealed: (a) Migrations are more frequent when the words are separated by smaller physical distances; (b) a majority of the migrations are a result of letters being copied from one word to the other, not from the interchange of letters of the two words; (c) migrations to a word are less frequent when subjects focus attention on that word; and (d) migrations are far more frequent when the words share letters in common. This last result suggests that migrations are not caused by a loss of spatial information at the letter level, that is, by free-floating letters being wrongly combined. Rather, migrations occur because of structural limitations at a high level of the word-recognition process, perhaps during lexical activation. Implications for models of multiple-word perception are discussed.

Letter Migration in Word Perception

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When we look at a page of text, many words appear simultaneously in our field of vision, yet we see each word individually and distinctly. We have no difficulty separating one word from the others. Indeed, it is hard to imagine that the perception of one word could be influenced by other words on the page. Nonetheless, the following examples from Wilkins (cited in Woodworth, 1938, p. 744) suggest otherwise:

Psychment
Departology

Woodson
Wilrow

talder
powcum

Shakesbeth
Macpeare

In a quick glance, people often misread these phrases in their familiar form. There are several reasonable explanations for such misreadings, the most obvious being that people examine only the first few letters of each word, and from this information the familiar phrases are inferred. The tendency to misread the phrases may be further compounded by the physical presence of the proper word endings, even though the endings are attached to the wrong words. That is, the endings "ment" and "ology" in the first phrase may supply perceptual evidence for the words "department" and "psychology," respectively.

Errors of a similar kind have been noted and studied by Allport (1977), Shallice and McGill (1978), and Shallice and Warrington (1977). Allport presented arrays of four unrelated words, all having the same number of letters, followed by a pattern mask. Subjects were to report as many words as possible from the display. Although Allport was primarily concerned with another issue, examination of the errors made by subjects revealed a large number of responses that might have been formed by combining letters of several words in the display. Shallice and McGill followed up this work by studying the effect of visual similarity among words in the array and by biasing responses with semantic cues. These experiments suggest that letters of one word in the visual field may be perceived as belonging to another, but there is a possible simpler and less interesting explanation. A subject might respond DENT to a stimulus display containing DUST and RENT, not because the "D" of DUST migrated to RENT, but because the "R" of RENT was incompletely or incorrectly registered, leading the subject to guess "D" instead.

The experiments reported here study the phenomenon further, first verifying that letter migrations are indeed the result of perceptual interactions among words in the visual field, and then looking at properties of the migrations in greater depth. In these experiments, pairs of four letter words were presented for brief exposures, and subjects were asked to report one or both of the displayed words. The stimulus word pairs were chosen so that either of two letters of one word could be substituted into the corresponding position of the other word to form a new word. For example, with the pair LINE and LACE, the "A" and "C" of LACE can migrate to LINE to form LANE and LICE,

respectively. Although only migrations between corresponding letter positions were studied, Allport observed that these were by far the most dominant sort.

The letter-migration phenomenon seems related to a class of speech errors known as *Spoonerisms*, which involve the interchange of phonemes of two nearby or adjacent words (Baars & Motley, 1976; MacKay, 1970); for example, transforming "barn door" into "darn bore." Interestingly, the interchanging phonemes almost always come from the same position in the two words, similar in this regard to the letter migrations observed by Allport. If a more complete analogy can be drawn between these two types of errors, models explaining Spoonerisms and the serial ordering of speech may help in understanding letter migrations and the segmentation of perceptual information. Experiment 2 examines just how similar in nature the two phenomena are.

Another possibly related phenomenon has been demonstrated by Treisman and Schmidt (1982). They found that when focal attention is diverted or overloaded, visual features of items in a multiple-item display can be wrongly combined, producing "illusory conjunctions" of the features. For example, if a subject were shown a display consisting of a red "T," a blue "O," and a green "X" arranged in a row, the subject might report seeing a red "X" in the center of the display or a blue "T" on the left.

Illusory conjunctions are predicted from the feature-integration theory of attention (Treisman & Gelade, 1980; Treisman, Sykes, & Gelade, 1977). According to this theory, perceptual processing is divided into two stages. At the first "feature-registration" stage, each object in the visual world is analyzed along a number of independent feature dimensions (e.g., shape, color, and size), and separate representations of the world are formed for each dimension. At the second "feature-integration" stage, unitary, integrated representations of objects are constructed by conjoining the various features belonging to each object. Feature integration is guided either by focal attention, which allows all features at a given spatial region to be bound together, or by past experience, which specifies how features might reasonably be conjoined. However, when attention cannot be focused serially on each object (as might be the case when brief stimulus exposures are used or when attention is distracted from the critical objects) and when past experience does not specify how to conjoin the features, features from the different dimensions may be incorrectly combined. Feature-integration theory thus suggests that illusory conjunctions result from the loss of, and ultimately the inability to recover, information about the spatial location of individual features.

Just as letter shapes behaved as separable features in Treisman and Schmidt's colored-letter demonstration, perhaps letter shapes might also behave as features in word perception. If this was true, letter migrations could be explained as a failure to correctly localize individual letters. Because within-word migrations and migrations to noncorresponding letter positions are probably rare, one might make the additional assumption that each letter position in a word defines a separate dimension. Thus, confusions may arise between letters in corresponding positions of two words (two features within the same dimension), but not between two letters in a single word (features in different dimensions). Experiments 2 and 3 examine whether the letter-migration phenomenon can be explained in the same manner as Treisman and Schmidt explained illusory conjunctions.

Experiment 1

This experiment demonstrated the letter-migration phenomenon in a controlled fashion. Subjects were shown pairs of horizontally adjacent words such as LINE and LACE for a brief duration and then were signaled to report a specific one of the words, say LINE in the present example.

To see how the perception of the "probe" word LINE is influenced by the irrelevant "context" word, responses to the probe in one context were compared against responses to the same probe in another context, for example, LINE in the context of LACE vs. LINE in the context of LOVE. When LACE is the context, error responses indicative of letter migrations from the context would be LANE, LICE, or even LACE, whereas when LOVE is the context, the error responses would be LONE, LIVE, or LOVE.

Responses to the probe can be divided into four categories: (a) correct responses, (b) "migration" error responses, which are those containing letters from the context word, (c) "unexpected" error responses, which are those containing letters from the nonpresented context word (e.g., with the probe LINE and context LACE, unexpected responses are those combining letters of LOVE with LINE, i.e., LONE, LIVE, and LOVE), and (d) all "other" error responses. The unexpected responses provide an estimate of the number of migration responses that are caused by guessing biases and perceptual difficulties in extracting letter features. Thus, the number of "true" migrations can be measured by subtracting the number of unexpected responses from the number of migration responses. If the context word has no effect on perception, the number of true migrations should be zero because subjects should respond LIVE in the context of LOVE (a migration response) as often as they respond LIVE in the context of LACE (an unexpected response).

All word pairs in this experiment had the same first and last letters. Experiments 3 and 4 studied word pairs with no common letters.

Method

Stimuli. Stimulus items were selected from the set of four-letter words contained in the Kucera and Francis (1967) corpus. Foreign words, abbreviations, acronyms, plurals, and words with repeated letters were excluded from the sample; proper nouns were not. A computer program considered each word in the corpus as a possible probe stimulus and tried to find two context words for the probe such that: (a) both context words had the same first and last letters as the probe; (b) neither the second nor third letter of a context word was contained in the probe word; (c) the second and third letters of one context word were different from those of the other; (d) new words ("conjunctions") were formed by moving either the second or third letter from a context word to the corresponding position of the probe. LACE and LOVE are allowable context words for the probe LINE because (a) all three words start with "L" and end with "E", (b) "A", "C", "O", and "V" are different from "I" and "N", (c) "A" and "C" are different from "O" and "V", and (d) LANE, LICE, LONE, and LIVE are all words.

There were 52 probe words for which at least one pair of context words existed. When more than one context pair existed for a particular probe, the pair that minimized word-frequency variance (between the probe, the two contexts, and the four conjunctions) was selected. On inspection, no probe was found to be semantically related to its two context words and possible conjunctions, with the exception of six verbs whose conjunctions included the same verb with a tense change (e.g., SPIT could combine with the context SLAT to form SPAT).

Twenty-five practice items consisting of a probe and a single context word were also generated using similar criteria as for the experimental set.

Subjects saw each probe twice, once in each of its two contexts. Seven probes also served as contexts for other probes, though no single word appeared as a probe and/or context more than three times total.

Viewing conditions. Subjects were seated in front of an AED 512 Color Graphics/Imaging Terminal (manufactured by Advanced Electronics Design, Inc.), on which pairs of words were presented side by side. The words were printed in bright red uppercase letters against a dark background. A 7X9 dot-matrix font was used to represent each letter. When centered on the fovea, the matrix subtended .28 degree of visual angle in the horizontal dimension and .37 in the vertical. The space between letters of a word was one dot wide.

One word was presented to the left of a fixation point and the other to the right. The last letter of the left word and the first letter of the right word were equidistant from fixation. Two word separation conditions were tested: In the "near" condition, the separation between words was 2.5 character spaces, making the pair of words subtend a 3.27 degree horizontal visual angle. In the "far" condition, the separation was 6 character spaces, making the pair of words subtend a 4.36 degree horizontal visual angle.

Except for a small portion of the screen where the words were shown, the screen was covered with a black posterboard to eliminate glare. Words were presented on the screen at eye level. A constant dim illumination was maintained in the room throughout the experiment.

Procedure. Subjects were tested individually. Each subject sat with the experimenter in a soundproof chamber. Before the experiment, the experimenter explained the procedure to be followed. Subjects were told that they would see only words, that proper nouns were allowed, that the first and last letters of the two words were the same, and that words could appear more than one time during the course of the experiment.

The 25 practice trials were followed immediately by the 104 experimental trials. Within the sets of practice and experimental trials, presentation order was chosen randomly for each subject. Subjects were allowed a short break halfway through the experiment.

Each trial began with the appearance of a red fixation point in the center of a red rectangle which subtended horizontal and vertical visual angles of 8.16 and 1.69 degrees, respectively. Subjects were instructed to fixate on the point and say "go" when they were prepared. The experimenter then initiated presentation of the word pair, which appeared for a controlled duration in the center of the rectangle. Following the words, a random dot mask the size of the rectangle flashed on the screen for 200 msec. The mask was an array of 200X40 red pixels, 60% of which were turned off at random.

Immediately following the mask, the rectangle reappeared with a bright green bar below the location where the probe word had been, indicating to subjects which word to report. Subjects were encouraged to report whatever they had seen, even if the letters did not form a word, but not to guess if they had only seen a few of the letters. Additionally, 16 of the 24 subjects were asked for a confidence rating from 1 to 4 indicating the certainty of their response. A rating of 1 indicated that

subjects were "absolutely positive" of their response, 2 indicated "fairly positive," 3 indicated "reasonably sure," and 4 indicated "not sure." Subjects were told not to base the rating on word familiarity or on whether they thought the probe was a word likely to appear in the experiment.

The experimenter recorded the reported word and confidence rating, after which the fixation point reappeared. Subjects were allowed to change their responses and confidence ratings until the next trial had been initiated.

The probe words appeared on the left as often as they appeared on the right for each subject. For practice trials, the position of each probe was chosen at random. For experimental trials, the position of each probe word was counterbalanced across subjects and contexts.

The exposure duration of the word pairs was set at 330 msec initially and was then varied to elicit an overall error rate of 30%. Any trial in which the response was not identical to the probe was considered an error. After every 10 trials (practice trials included), the exposure duration was adjusted in 17-mec steps depending on the number of errors made during the previous 10 trials. The mean exposure duration over all trials was 348 msec, with a range across subjects of 262 to 425 msec.

Because the exposure-adjustment procedure was not always effective, subjects whose error rates were outside of the range 15-45% were eliminated from the experiment.

Subjects. Twenty-four undergraduates at the University of California at San Diego received course credit for participating in the experiment, which lasted approximately 30 min. All subjects were native English speakers.

Three subjects were replaced because their error rates could not be controlled. Two had 10% error rates, the third a 46% error rate.

Results and Discussion

Responses to the probe word were divided into four categories: correct responses, migration error responses (those containing letters from the presented context word), unexpected error responses (those containing letters from the nonpresented context word), and all other error responses (including trials in which subjects gave no response). Table 1 shows the distribution of responses, broken down by word separation and probe position. The overall error rate was 31.49%; therefore the exposure-duration manipulations seem to have been successful in controlling the error rate.

There were significantly more migration errors than unexpected errors (for the subjects analysis, $F(1, 22) = 41.7$, $p < .001$; min $F'(1, 58) = 22.1$, $p < .001$, computed from formulas given in Clark, 1973), indicating that at least some of the migration errors were true migrations. The percentage of true migrations can be estimated at 8.1% by subtracting the percentage of unexpected errors from the percentage of migration errors.

Over 95% of the migration errors were made when a single letter migrated from the context word to the probe; the remainder of the errors involved the simultaneous migration of both middle letters.

Table 1

Experiment 1

Percentage of Responses Falling into Each Response Category
by Word Separation and Probe Position

	Word separation				
	Near		Far		
	Probe position		Probe position		
	Left	Right	Left	Right	Overall
Correct responses	74.84	65.06	77.24	56.89	68.51
Migration errors	13.62	16.35	9.46	15.38	13.70
Unexpected errors	2.40	6.09	3.84	9.94	5.57
Other errors (including no response)	9.14	12.50	9.46	17.79	12.22
True migrations[a]	11.22	10.26	5.62	5.44	8.13

[a]The percentage of true migrations is computed by taking the difference between the percentage of migration and unexpected errors.

The results clearly show that letters of one word in a display can be perceived as belonging to another word in the display. Unlike the earlier work of Allport (1977) and Shallice and McGill (1978), this experiment controls for guessing biases that may produce artifactual letter migrations. These controls do seem important, as evidenced by the large percentage of unexpected errors.

Word-separation effects. The true migration rate was 10.74% in the near condition (when probe and context words were separated by 2.5 character spaces), but was only 5.53% in the far condition (probe and context separated by 6 character spaces). The difference between these rates was significant: for the subjects analysis, $F(1, 22) = 4.28$, $p = .05$; for the probes analysis, $F(1, 51) = 11.33$, $p < .001$; for the combined analysis, $2.98 < F'(1, 38) < 3.36$, $.075 < p < .10$.

To attribute this difference to word separation, two alternative explanations must be ruled out: (a) that the difference was due to a higher overall error rate in the near condition; (b) that because the experimental manipulation forced error rates to be close to 30%, if difficulties in perceiving individual words caused the proportions of unexpected and other errors to be larger in the far condition, the proportion of migration errors would necessarily have been smaller. The first explanation is easy to rule out: The error rate was 30.1% in the near condition and 32.9% in the far. As for the second explanation, it seems doubtful that data limitations were introduced by the greater foveal eccentricity of words in the far condition because the average exposure durations required to elicit the 30% error rate were comparable in the two conditions: 339 msec in the near condition versus 359 msec in the far, $F(1, 22) = 2.07$, $p > .10$.[1]

Thus, there is reasonable, though not irrefutable, evidence that the frequency of migrations is affected by word separation even though the perceptibility of individual words is not. This suggests that the letter-migration phenomenon is perceptual in nature. If migrations resulted from memory confusions rather than perceptual confusions, manipulation of the display (increasing word separation) would not have affected the migration rate. The perceptual "feel" of the phenomenon is substantiated by introspective reports from subjects and experimenters alike.

Probe-position effects. The true migration rate for probes appearing on the left was not significantly different than that for probes appearing on the right: 8.42% versus 7.85%, $F(1, 22) < 1$, max $F'(1, 55) < 1$. Thus, true migrations from the left word to the right were roughly as frequent as from the right word to the left.

Note that two possible metrics could be used to compare left and right probe migrations: either the true migration rate (the "absolute rate") or the true migration rate divided by the overall error rate (the "conditional rate"). The absolute rate was used before, but one might argue that this metric is inappropriate as it may be influenced by the overall error rate (i.e., when fewer errors occur overall, there are correspondingly fewer opportunities for migration errors). Subjects did make far fewer errors in response to left probes: 23.95% overall error rate on the left, 39.02% on the right, $F(1, 22) =$

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1. One might argue that exposure durations can only be compared when the error rates in the two conditions are equal, and, as noted here, the error rate in the far condition was slightly, though nonsignificantly, larger. Perhaps the additional exposure that would have been required to reduce the error rate in the far condition would have led to a significant difference in exposure duration between conditions. Consequently, the "decreased perceptibility" explanation for the word-separation effect cannot be entirely discounted.

9.16, $p < .01$; min $F'(1, 31) = 7.82$, $p < .01$. Had the overall error rates been comparable, perhaps the left probe migration rate would have been larger than the right probe rate. Therefore, the conditional rate seems to be a better metric because it corrects for the total number of errors.

However, this reasoning is fallacious, for the conditional rate has the same problem as the absolute rate: It is dependent on the overall error rate. To clarify this point, suppose that the present experiment was conducted again, and the overall error rate was set to 95% not 30%. To achieve a 95% error rate, exposures would have to be extremely brief. At such brief exposures, subjects would be unable to acquire much perceptual information from the display, and most of their errors would result from haphazard guessing. Consequently, migrations would be rare, and the conditional rate would be negligible compared to the conditional rate in the present experiment.

Given that neither absolute nor conditional rates are independent of the overall error rate, whichever metric one chooses is theory dependent. The choice of absolute rates will make sense when the left-right effects of this experiment are contrasted to those found in Experiment 2.

Confidence ratings and subjective experience. Confidence ratings were obtained for eight subjects in the near condition and eight in the far condition. The ratings, which ranged from 1 to 4 with a smaller number indicating greater certainty, were converted to z scores for each subject. Table 2 shows the mean confidence ratings broken down by response category. There was a significant difference in response certainty between correct and migration responses, $F(1, 15) = 372.6$, $p < .001$, and between unexpected and other error responses, $F(1, 15) = 9.48$, $p < .05$, but not quite between migration and unexpected error responses, $F(1, 15) = 3.31$, $p > .05$.

Although one cannot conclude that subjects were more confident when making migration error responses than unexpected error responses, there is evidence that subjects did perceive at least some conjunctions with certainty. When examining their data after the experiment, subjects were often quite surprised that particular responses were conjunctions, as they distinctly remembered seeing the words. Shallice and McGill (1978) also noted that subjects expressed high confidence when making migration error responses. In fact, when they increased the exposure duration, subjects' confidence in the correctness of migration errors also increased.

Often, however, subjects would notice errors and correct themselves immediately (in which case the corrected response was recorded). For example, one subject saw the probe SPIT and context SHOT, responded SPOT, then exclaimed, "Oh, I meant SPIT. Why did I say SPOT?". The wrong word often seemed to slip out, even though subjects were consciously aware of having seen the correct word.

Included among these slips were responses of more than four letters. One subject saw BAKE and BLUE and initially responded BLAKE. Almost half the subjects saw SPAT and SLIT and responded SPLAT or SPLIT. In other instances, however, subjects reported five-letter words and the fifth letter did not come from either word in the display. Day (1977) discussed a similar auditory phenomenon in which dichotic pairs of items such as BANKET and LANKET were presented simultaneously and subjects reported hearing not two separate words, but the single fused word BLANKET.

Table 2

Experiment 1

Mean Confidence Ratings (of 16 subjects) by Response Category

	Mean confidence rating	
	Actual rating	*z* score
Correct responses	1.39	-.42
Migration errors	2.50	.61
Unexpected errors	2.74	.89
Other errors (including no response)	3.40	1.36

Note. Smaller ratings indicate greater confidence in making the response.

Experiment 2

This experiment investigated whether letters of the two words exchange places when migrations occur or whether letters of one word copy to the other word, overwriting the replaced letters. For example, if LINE and LACE were presented and subjects were asked to report both words in the display, would they make error responses like LANE and LICE (an *exchange*) or like LINE and LICE (a *copy*)?

Copy errors are foreign to both Spoonerisms and illusory conjunctions. Spoonerisms are, by definition, exchanges. In fact, Baars and Motley (1976) have shown that preentry of a phoneme from the second of two words is sufficient to trigger postentry of a phoneme from the first word; that is, the phoneme driven out of the first word jumps into the gap left behind by the other phoneme.

Illusory conjunctions seldom involve copies; features generally leave no trace behind when they move to a different location (Treisman & Schmidt, 1982). Further, it does not seem that feature-integration processes, which bind free-floating features to spatial locations, should introduce "ghost" copies of features. Although feature-integration theory does not explicitly rule out the formation of copies, such a possibility does not seem parsimonious to the theory. Thus, if letter migrations are similar in nature to either Spoonerisms or illusory conjunctions, most migrations ought to be exchanges.

Method

Stimuli. Stimulus words were drawn from the Kucera and Francis (1967) corpus used in Experiment 1. As in Experiment 1, each word pair was chosen so that two letter positions (the "nontested" positions) contained the same letters in both words and the other two positions (the "tested" positions) contained letters that could interchange to form new words. Four pairs of tested positions ("test sets") were used in the experiment: 1/2, 2/3, 3/4, and 1/4. PANT and RUNT is an example of test set 1/2 because positions 1 and 2 can migrate to form RANT and PUNT, and positions 3 and 4 are the same in both words. Likewise, CANE and COPE is an example of test set 2/3, FILE and FIRM of test set 3/4, and HANG and RANK of test set 1/4.

When all word pairs in the corpus were analyzed, several hundred candidates were found for each test set. Forty pairs were then chosen from each test set to make a total of 160 experimental trials. Twenty practice trials were chosen from the remaining pairs, five from each of the four sets. The pairs selected were those having the smallest variance in the logarithm of the frequency counts of the two stimulus words and two words that could be formed by combining letters of the stimulus words. Pairs with obviously confusable letters in the test positions (e.g., R and P, M and N) were excluded. In the experimental trials, no word appeared more than four times, and a great majority appeared only once or twice.

Across all subjects, each pair member was presented equally often on the left as on the right. Viewing conditions were the same as in the near condition of Experiment 1.

Procedure. The procedure was identical to that of Experiment 1, except subjects were instructed to report both words in the display, starting with the word on the left. The probe bar was not used.

Any trial in which either response word was not identical to its corresponding stimulus word was considered an error. The mean exposure duration was 353 msec, and the overall error rate was 30.55%.

Subjects. Sixteen undergraduates at the University of California at San Diego received course credit for their participation. All were native English speakers, and none had taken part in Experiment 1. Using the criteria of Experiment 1, two subjects had to be replaced because of uncontrollable error rates; one had a 1% error rate, the other a 46% error rate.

Results and Discussion

Responses obtained from each word pair were classified into one of the following categories: (a) "correct responses" (both words reported correctly), (b) "L-R copies" (a letter from the left word copied to the corresponding position of the right word), (c) "R-L copies" (a letter from the right word copied to the corresponding position of the left word), (d) "exchanges" (a letter from the left word exchanged locations with the corresponding letter of the right word), and (e) "other errors" (all other responses). Although it was possible for a single response to be classified into more than one of these categories (e.g., a response of CAPE and CANE to CANE and COPE involves both a L-R copy in position 2 and an exchange in position 3), response classification was simplified by the fact that no response was observed in which migrations occurred from both tested letter positions simultaneously. Table 3 shows the distribution of responses by category, collapsed across test set.

Several responses that could have been either copies or exchanges were classified as "other" errors; for example, a response of COPE and CAVE to COKE and CAPE. It is impossible to determine whether the "P" in position 3 copied or exchanged because the "V" is an intrusion. Only four responses of this type were made across all subjects; therefore it did not matter how they were classified.

One comment regarding the data: This experiment had no control condition from which the unexpected error rate could be estimated. Thus, one cannot judge how many of the observed migration responses were true migrations. Nonetheless, the results that follow would seem to hold true under any reasonable assumptions for the baseline error rates.

Copies versus exchanges. As Table 3 shows, there were far more letter copies than exchanges: 10.71% of all responses were copies and only .86% were exchanges. This result was found to be consistent across the four letter positions.

Although letter migrations are generally the result of copies, Spoonerisms are exclusively exchanges. This is a fundamental difference between the two phenomena.

The overwhelming number of copies also hints that letter migrations are different in nature from illusory conjunctions. This in turn hints that feature-integration theory may not provide the appropriate framework for the study of letter migrations. Experiment 3 further examines the relation between letter migrations and the feature-integration framework.

Direction of letter copies. There were significantly more L-R than R-L copies, $F'(1, 15) = 7.69$, $p < .05$; min $F'(1, 31) = 5.27$, $p < .05$. The predominance of L-R copies is unexpected in light of Experiment 1, which found as many R-L (left probe) migrations as L-R (right probe). The

Table 3

Experiment 2

Percentage of Responses Falling into Each Response Category

Correct responses	69.45
Left-to-right copies	7.23
Right-to-left copies	3.48
Exchanges	.86
Other errors	18.98

discrepancy between the two experiments cannot be attributed to the use of varied test sets in Experiment 2; when word pairs from test set 2/3, the set comparable to the stimulus set used in Experiment 1, were examined separately, L-R copies were still more common: 10.3% of the responses were L-R copies, contrasted with 2.97% R-L copies and 1.09% exchanges.

The discrepancy must stem from the only real difference between the experiments: the report procedure. In Experiment 1, subjects did not know which word was to be reported until the probe bar appeared. There was a delay between stimulus and probe bar onsets, during which time the best strategy for subjects would have been to distribute attention evenly between the words. However, because both words had to be reported in Experiment 2, subjects had no reason to concern themselves with the right word before the left word had been perceived; most subjects consciously adopted a strategy of focusing attention initially on the left word. Thus, it appears that focusing attention on one of the words in the display can lower the migration rate to that word with respect to the rate to the other.

However, a weak point in this argument should be noted. In Experiment 1, the overall error rate on the left was less than on the right (11.98% of all responses vs. 19.51%), though not as much less as in Experiment 2 (8.13% vs. 25.15%). Had subjects been dividing attention evenly in Experiment 1, the error rates should probably have been equal. It is not surprising that a left-to-right processing bias is evident given ordinary reading habits and exposure durations long enough to allow eye movements to at least one of the words. What is surprising is that despite the slight bias, the migration rates for left and right probes were no different. Perhaps the overall error rate is more sensitive to attentional biases than is the migration rate.

Experiment 3

In Experiments 1 and 2, corresponding nontested letters of the stimulus words were identical, for example, the "C" and "E" of CAPE and CONE. What would happen if the probe CAPE were presented in the context of MONK, which has the same tested letters as CONE but different nontested letters? If words are represented as collections of separate letters at the level of visual information processing in which migrations occur, then migrations of a letter should not be affected by the identities of the nontested letters. On the other hand, if migrations are a product of interactions between higher level word representations, then the context in which a letter is embedded may well influence migrations. The results of Shallice and McGill (1978) appear to indicate that decreasing the similarity between words reduces the number of migrations.

In addition to similarity, Experiment 3 also examined the effect of attention on migrations. In Experiments 1 and 2, focal attention was limited by brief stimulus presentations. However, this indirect means of control may not have been effective given the relatively long exposure durations used. Because of the critical role attributed to attention in the formation of illusory conjunctions, and because of the attentional effects on migration rates observed in Experiment 2, a condition was included in Experiment 3 to manipulate attention directly. Half of the subjects in Experiment 3 were given a distractor task along with the main word-perception task to further limit focal attention on the words.

Experiment 3 followed the design of Experiment 1, with the inclusion of a digit-reporting task like the one used by Treisman and Schmidt (1982). Subjects in the "digit" condition were presented with a large blue digit at either end of the display and were to report first the digits and then the

probe word. Subjects in the "no-digit" condition were shown the same word pairs but without the digits.

Subjects saw each probe twice, once with an "exchange" context and once with a "control" context. Two letters of the exchange context could migrate, either individually or jointly, to the probe to form new words. The control context was chosen so that neither of the tested positions could migrate to the probe to form a new word. For example, the probe CAPE had exchange context MONK and control context BULK.

Method

Stimuli. Stimulus words were drawn from the Kucera and Francis (1967) corpus. Three test sets were used: 1/2, 2/3, and 3/4. For each test set, all probe-exchange-control triples were found that met the above criteria, in addition to the following: (a) neither nontested letter of the context words could migrate, individually or with the other nontested letter, to the probe and form a word; (b) no position of the control context and the probe could contain the same letter; and (c) the two tested letters of the exchange context could not appear in any position of the control context or in either nontested position of the probe or exchange context.

Within each test set, the 20 triples that best matched in word frequency were chosen as experimental triples. Ten of the next best probe-exchange pairs from set 2/3 and five from sets 1/2 and 3/4 were chosen as practice trials. The index of word-frequency match was the variance in the logarithm of the frequency counts of the probe, exchange, control, and the three words that could be formed by combining letters of the probe and exchange context.

There were a total of 120 experimental trials (three test sets each having 20 probes appearing in two contexts) and 20 practice trials. Only one word appeared as both a probe and a context.

Viewing conditions were the same as in Experiment 2. In the digit condition, two large blue digits appeared beside the words, one at either end of the display. The digits ranged from 1 to 9 and were chosen at random. Each digit was centered 3.05 degrees from fixation and subtended horizontal and vertical visual angles of .85 and 1.26 degrees, respectively. The color blue was chosen to contrast sharply with the red words.

Procedure. The general procedure was identical to that of Experiment 1. In the digit condition, subjects were instructed that reporting the digits was their primary task and that they were not to concentrate on the words until the digits had been reported, first the digit on the left then the one on the right. The initial exposure duration was 310 msec for subjects in the no-digit condition and 383 msec for subjects in the digit condition.

Subjects. Sixteen undergraduates at the University of California at San Diego received course credit for their participation. All were native English speakers, and none had taken part in Experiments 1 or 2. Using the criteria mentioned in Experiment 1, two subjects in the no-digit condition had to be replaced because of uncontrollable error rates; one had a 10% error rate, the other a 14% error rate.

Results and Discussion

The overall error rate was 28.9% in the no-digit condition and 34.2% in the digit condition. Subjects in the digit condition required substantially longer exposure durations to yield the desired error rate (428 msec vs. 229 msec in the no-digit condition), though they were able to report over 98% of the digits correctly.

Note that the 229-msec average exposure in the no-digit condition is significantly shorter than the 339-msec average exposure in the near condition of Experiment 1, $F(1, 18) = 7.93$, $p < .05$. The procedure for these two experimental groups was identical and the stimuli were similar, except with regard to the nontested letters of the context word. The difference in exposure duration provides another demonstration of interactions between words: It is easier to correctly perceive the probe when the context has fewer letters in common with it.

Responses to the probe in this experiment were divided into four categories: "correct" responses, "migration" error responses (when the exchange context was presented and letters from the test positions of the exchange context appeared in the response), "unexpected" error responses (when the control context was presented and letters from the test positions of the exchange context appeared in the response), and all "other" error responses.

Table 4 shows the percentage of migration and unexpected error responses, broken down by distractor condition and probe position, collapsed across test set. The percentages for a particular response type are computed with respect to the total number of trials that could produce that response. In both distractor conditions and probe positions, the percentages of true migrations were nonsignificant: for each of the four groups, $F(1, 7) < 1.5$, $p > .30$; for the pooled responses, $F(1, 15) = 1.97$, $p > .15$. Within test set 2/3, which tested the same positions as Experiment 1, the true migration rate was .6% in the no-digit condition and 0% in the digit condition.

Although the true migration rate was negligible here, it was 10.74% in the near condition of Experiment 1. Thus, migrations are far less likely when a probe (e.g., CAPE) is presented in the context of a word having no common letters (e.g., MONK), as in Experiment 3, than in the context of a word having some common letters (e.g., CONE), as in Experiment 1. This result supports the findings of Shallice and McGill (1977).

Because migrations of one letter in a word are dependent on the identities of the other letters, words must not be coded as collections of independent letters at the level of visual information processing in which migrations occur. That is, migrating letters do not behave as separable "features" of a word in the sense of feature-integration theory. Thus, feature-integration theory does not seem to be the appropriate framework for the study of letter migrations.

Distractor condition. The percentage of true migrations was 1.67% in the digit condition and 1.04% in the no-digit condition. These percentages are nearly identical and nonsignificant; the digit-reporting task did not cause an increase in migrations.

In the no-digit condition, focal attention on the words was limited by brief exposure durations. In the digit condition, attention was meant to be further diverted by the digit-reporting task. However, this task may not have achieved its purpose; the average exposure in the digit condition was almost 200 msec longer than in the no-digit condition, and this additional exposure may have offset

Table 4

Experiment 3

Percentage of Migration and Unexpected Error Responses
by Distractor Condition and Probe Position

	Distractor condition			
	Digit		No digit	
	Probe position		Probe position	
	Left	Right	Left	Right
Migration errors	7.92	6.68	5.83	6.67
Unexpected errors	4.17	7.08	5.42	5.00
True migrations[a]	3.75	-.40	.41	1.67

[a]The percentage of true migrations is computed by taking the difference between the percentage of migration and unexpected errors.

the attentional demands of the digit-reporting task. From the subjects' viewpoint, however, this was not so. Subjects claimed to have followed instructions, attending to the words only after the digits had been perceived and "stuck in an output buffer." Indeed, subjects started reporting the digits prior to stimulus offset, and they felt great strain in trying to accomplish the word-perception task while reporting the digits. Thus, it appears that attention was distracted by the digit-reporting task, though not as much by perceptual aspects of the task as by the verbal reporting of the digits.

An interesting difference was found between the distractor conditions. Although subjects had been carefully instructed before the experiment to report only the probe, every subject in the digit condition occasionally reported the context word instead. In the digit condition, 3.96% of all responses were "word migrations" of this sort, whereas no word migrations were observed in the no-digit condition. Word migration errors cannot be attributed to a proportionately greater number of errors overall in the digit condition, as the other-error rates in the digit and no-digit conditions were comparable (27.71% vs. 23.12%).

Because the probe and the context shared no letters in common, word migrations required the joint migration of all four letters of the context. Given the negligible number of letter-migration errors, it seems highly improbable that word migrations were due to multiple letter-migrations. Instead, words must have migrated as single units. Thus, when attention is distracted, a word can be correctly identified without being correctly localized. Allport (1977) also found identification of words possible without localization. This result is in accord with the subjective experience of glancing at a page of text, seeing a word, but being unsure of where the word appeared on the page; or of substituting a word from elsewhere on the page into a line being read.

Surprisingly, although letter migrations could not be accounted for within the framework of feature-integration theory, it does seem like feature-integration theory may be appropriate for explaining word migrations. According to feature-integration theory, identification without localization can occur only for features of a scene. The identities of features are coded at an early stage of perception, and if focal attention is not applied at a later stage, identified features may be localized incorrectly. However, before an object that is a conjunction of features can be identified, it must be localized by focal attention in order to integrate its features. For example, Treisman and Gelade (1980) found that subjects could detect target colors or letters in a display without being able to report the target location correctly, yet they could not do so for targets that were a conjunction of color and letter shape.

Thus, the mislocation of entire words when attention is distracted suggests that words can behave as "features" in the sense of feature-integration theory (for a similar proposition, see Allport, 1977). Although this account of word migrations seems adequate, it points out a need to explicitly characterize the "features" of feature-integration theory.

Experiment 4

This experiment was designed to clear up several ambiguities and problems encountered in the earlier experiments.

First, in the earlier experiments, word pairs were exposed for a large fraction of a second, long enough for subjects to make eye movements from the fixation point to one word, and perhaps from one word to the other. Migrations may have resulted from one word being superimposed over the

other on the retina, thus being temporal rather than spatial in nature. To rule out this possibility, eye movements were prevented in Experiment 4 by presenting the word pairs for only 50 msec, followed by a blank field of variable duration.

Second, stimulus words in the earlier experiments often appeared multiple times during a session. Partial word activations left over from one presentation of a word may have biased the perception of the next presentation. Experiment 4 prevented contamination from word repetitions by presenting each probe only once during a session.

Third, in the earlier experiments, exposures were unusually long, considering that single words presented tachistoscopically can be accurately perceived in well under 50 msec (Rumelhart & McClelland, 1982). The long exposures required may be partially attributable to perceptual interactions between words in the display, but perception may also have been impaired by the visual quality of the stimuli. Letters within a word were separated by only one pixel space (1/7th the width of a letter) and appeared somewhat indistinct. To reduce lateral interference, Experiment 4 doubled the spacing between letters.

Fourth, Experiments 1 and 2 found little evidence for the simultaneous migration of the two tested letters of a word pair; fewer than 5% of migration responses in Experiment 1 involved both tested letters, and no response in Experiment 2 contained a double-letter migration. However, because these migrations would have caused the same word to be seen in both positions of the display, subjects may have had a bias against reporting them. To reduce this bias, Experiment 4 included several trials with identical words.

Fifth, letter migrations were not found in Experiment 3, where the nontested letters of the context were different than those of the probe. However, Experiment 3 may not have been sensitive enough to detect a small effect. Consequently, Experiment 4 replicated Experiment 3 using a larger number of subjects and probes. Experiment 4 also made an explicit comparison of contexts having nontested letters identical to those of the probes ("same contexts") and contexts having nontested letters different than those of the probes ("different contexts").

Method

Stimuli. Four test sets were used: 1/2, 2/3, 3/4, and 1/4. For each test set, 42 word triples consisting of a probe, different context, and control context were found using the selection criteria of Experiment 3. A same context was constructed by transferring the two nontested letters of the probe to the different context. For example, the probe CAPE had MONK as its different context and CONE as its same context. No probe was allowed to appear as a same, different, or control context for any other probe.

Subjects saw each probe only once, in one of the three contexts. Trials were divided evenly among same, different, and control contexts within each test set for each subject. Across all subjects, each probe appeared equally often in its three contexts. Probe position was counterbalanced across subjects and contexts.

Twenty practice trials were generated using mainly same contexts. Within the sets of practice and experimental trials, presentation order was chosen randomly. Interspersed among the practice trials were three dummy trials in which the same word appeared in both positions, and interspersed

among the experimental trials were two more of these dummy trials. Responses from these trials were ignored, except to adjust the exposure duration.

The visual angle of each word in the display was the same as in Experiment 3, as was the visual angle of the space separating words, though the space between letters of a word was doubled and the letters were made smaller.

Procedure. The procedure was identical to that of Experiment 3, except for the manner of stimulus presentation; word pairs were presented for a constant duration of 50 msec, followed by a blank field of variable duration and then the random dot mask. The blank field lasted 200 msec initially, and was adjusted after every 10 trials to yield a 30% overall error rate.

Although stimuli were presented for only 50 msec, they remained visible for some short time afterwards due to phosphor persistence. The phosphor of the CRT decays to 20% of its original luminescence after 33 msec. However, to accurately determine the length of time that stimuli remain visible, the original stimulus intensity must also be known. The original intensity was not measured, but it seems highly unlikely that the words were legible for the additional length of time required to make an eye movement (approximately 150 msec).

Subjects. Twenty-four students and staff members of the University of California at San Diego received $3 for their participation. All were native English speakers, and none had taken part in the earlier experiments.

Results and Discussion

Each response was classified as being either correct, a migration error response (when the same or different context was presented and letters from the tested positions of the context appeared in the response), an unexpected error response (when the control context was presented and letters from the tested positions of the same or different context appeared in the response), or an other error response. Table 5 shows the distribution of responses, broken down by context type and probe position, collapsed across test set.

For both same and different contexts, the overall percentage of true migrations was significantly greater than zero -- same: $F(1, 23) = 48.1$, $p < .001$; min $F'(1, 57) = 29.26$, $p < .001$; different: $F(1, 23) = 9.68$, $p < .01$; min $F'(1, 86) = 4.41$, $p < .05$ -- although there were far more same- than different-context true migrations, $F(1, 23) = 26.3$, $p < .001$; min $F'(1, 67) = 14.46$, $p < .001$. The greater sensitivity of this experiment thus reveals, contrary to the findings of Experiment 3, that letters of the different context can migrate, though they do so at a much lower rate than letters of the same context. The present results also show that letter migrations occur even when eye movements are prevented and when repetitions of probe words are not allowed.

In Table 5, significantly more other errors were produced in the presence of same contexts than in the presence of different contexts: 24.85% vs. 19.20%, $F(1, 23) = 7.65$, $p < .05$; min $F'(1, 57) = 4.80$, $p < .05$. Thus, same contexts not only yielded a higher migration rate but also complicated perception in other respects. Because the similarity between probe and context seems to affect the error rate in subtle ways, the control context, which has no letters in common with the probe, may not provide an accurate estimate of the same-context unexpected error rate. Perhaps a "same-control" context (a context having the same nontested letters as the same context, but different letters in the tested

Table 5

Experiment 4

Percentage of Responses Falling into Each Response Category
by Context Type and Probe Position

	Context type					
	Different		Same		Control	
	Probe position		Probe position		Probe position	
	Left	Right	Left	Right	Left	Right
Correct responses	66.82	82.74	49.26	77.98	65.18	84.67
Migration errors	6.84	5.21	15.77	7.29	—	—
Unexpected errors	—	—	—	—	4.91	2.38
Other errors	26.34	12.05	34.97	14.73	29.91	12.95
True migrations[a]	1.93	2.83	10.86	4.91		

[a]The percentage of true migrations is computed by taking the difference between the percentage of same- or different-context migration errors and the control-context unexpected errors.

positions) would have resulted in a slightly higher unexpected error rate, and therefore a slightly lower same-context true migration rate.

Probe position effects. The overall left probe error rate was 39.5%, as compared to 18.2% for right probes. In the earlier experiments, however, overall error rates were consistently higher for right probes. The difference in error rates can be explained by the stimulus presentation conditions. In Experiment 4, the short 50-msec exposure prevented eye movements. Because fixating at a point ordinarily serves to gather information about words to the right of fixation (McConkie, 1979; Rayner, Well, & Pollatsek, 1980), the quality of perceptual data in the right visual field was probably higher, allowing the right word to be perceived more accurately. In the earlier experiments, however, exposure durations were long enough that subjects could move their eyes to and focus attention on either word. Because of natural left-to-right reading habits, focal attention was probably directed to the left word, and doing so overrode the preattentive right-visual-field advantage.

True migration rates to left and right probes were not significantly different for different contexts, $F(1, 23) < 1$. For same contexts, the left probe true migration rate was greater than the right probe rate, $F(1, 23) = 7.93$, $p < .01$; min $F'(1, 69) = 4.27$, $p < .05$, but I argued earlier that true migration rates in this condition may be inaccurate. If the difference in rates is accurate, however, it might be due to the right-visual-field advantage, which gave rise to a smaller number of errors of every sort for right probes.

Double-letter migrations. In 9.42% of same-context and 12.5% of different-context true migrations, the two tested letters of the context jointly transferred to the probe. Fewer double-letter migrations were reported in Experiments 1 and 2, presumably because of response biases. Although it would be interesting to learn whether double-letter migrations were a result of independent migrations occurring simultaneously in the two tested positions, the small number of letter migrations overall prevented a statistical test. In any case, the main result is clear; pairs of letters generally do not cohere and migrate together.

Letter spacing effects. It was thought that increasing the spacing between letters of a word would facilitate perception, thereby reducing the exposure duration required for a 70% correct-response rate. However, the average interval from stimulus onset to mask onset in the present experiment was not much smaller than the interval in the no-digit condition of Experiment 3 (220 vs. 225 msec), though it should be noted that the present experiment was somewhat more difficult than Experiment 3 because stimuli were displayed for only 50 msec, and because one third of the trials involved same contexts, a condition shown earlier to complicate perception.

Although the long exposure durations required may have been a consequence of perceptual interactions between words, it seems plausible that the long exposures were partly due to qualities of the stimulus display. Letters on our CRT display were not as sharply defined as on a tachistoscope; there was a brightness gradation at their contours. Also, the letters were red, which is unusual in a word-perception task.

Letter position effects. Table 6 shows the percentage of migration and unexpected error responses by letter position. Migration-response rates have been averaged over same and different contexts. Migrations did occur in all four positions, though it appears that the true migration rate increases for successive positions within a word.

Table 6

Experiment 4

Percentage of Migration and Unexpected Error Responses by Letter Position

	Letter position			
	1	2	3	4
Migration errors (average of same and different context)	1.71	4.10	7.22	5.73
Unexpected errors	.30	1.79	4.46	.89
True migrations	1.41	2.31	2.76	4.84

Note. Percentages for a particular response type are computed with respect to the total number of trials that could produce that response.

General Discussion

This study has shown that two distinct words in the visual field can interact, causing perceived migrations of letters from one word to the other. Letter migrations appear to be perceptual in nature because increasing the distance between words, a manipulation of the display format, lowers the frequency of migrations.

I attempted to tie the letter-migration phenomenon to two seemingly related phenomena: Spoonerisms and illusory conjunctions. However, these two phenomena were found to be qualitatively different from the letter-migration phenomenon. Spoonerisms are, by definition, *exchanges* of phonemes, whereas a majority of migrations involve *copies* of letters from one word to another; and illusory conjunctions result from the failure to recover spatial information about individual "features" in the display, but letter migrations are caused by a different process. To elaborate on this second difference, one might suppose that words are coded at some level of visual information processing as collections of single letters, and that migrations occur when letters from two words are mistakenly combined. However, letters do not function as separable "features" of a word: The frequency of migration of one letter in a word depends on the identities of the other letters.

At what level of perceptual processing do migrations occur? To approach this question, it is useful to consider each word as being processed along certain channels in the visual system. The phenomenon suggests that when two words appear simultaneously in the visual field, the channels along which one word is processed are not totally distinct from the channels along which the other word is processed. Where channels overlap, information contained in the channels can become confused, and letter migrations may result. Because migrations of one letter are dependent on the identities of the other letters, the overlap must occur along channels bearing higher order word information, not information about single letters. Further, the scarcity of double-letter migrations in all experiments hints that the overlap does not occur along channels bearing information about small letter clusters.

The overlap may occur in the activation of lexical knowledge (see Shallice & McGill, 1978, for a related proposal). Suppose that the internal lexicon does not explicitly distinguish between activations from various positions in the visual field. If several words in the visual field could activate the lexicon simultaneously, the pattern of activation produced by one word would interact with the pattern of activation produced by another word. For example, consider the presentation of COPE in the context of CANE. COPE activates a representation of itself, and in the process, partially activates what McClelland and Rumelhart (1981) call "cohorts," visually, orthographically, or phonetically similar words such as CAPE, CONE, CODE, and DOPE. An analogous situation occurs for CANE. Thus, both COPE and CANE partially activate representations of the conjunction words CAPE and CONE. If the net activation of either conjunction word surpasses the activation of the probe COPE, the conjunction word will be perceived. This activation hypothesis can therefore explain how apparent migrations of individual letters are produced. [2]

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2. Grudin (1981) argued for an activation hypothesis to explain typing errors that is similar to the one presented here, except that in the case of typing, partial activations give rise to motor, not perceptual, errors.

This activation hypothesis can also explain why more letter migrations are observed from same contexts than from different contexts. The less similar the probe and context, the less likely that activations from the context will interfere with those from the probe. The context CANE activates CAPE and CONE to a higher degree than does the context SANK because CANE shares three letters with CAPE and CONE, whereas SANK shares only one.

Implications for Models of Multiple-Word Perception

Models of word perception (Adams, 1979; Estes, 1975; LaBerge & Samuels, 1974; McClelland & Rumelhart, 1981; Morton, 1969) deal primarily with the recognition of single words in known locations. However, the experiments reported here, as well as others (Allport, 1977; Bradshaw, 1974), suggest that more than one word can be processed at a time. How might these models be expanded to process multiple words in various locations? Several of the present results have implications for models of multiple-word perception.

Perceptual interactions among words. The letter-migration phenomenon suggests that multiple words in the visual field are processed along channels that overlap as higher order word information is being coded. The activation hypothesis proposes one way in which the overlap might occur.

Separation of a word's identity from its location. Experiment 3 showed that when attention is diverted, entire words can be identified without being localized correctly. Following the framework of feature-integration theory, this result suggests that representations of words after the "feature-registration" stage of perception do not retain precise spatial location information. Focal attention or some other mechanism in the "feature-integration" stage is required to help recover this information.

Integration of information across fixations. It is interesting to consider that the mechanism producing letter migrations may also be involved in the integration of information across fixations, a problem extensively studied by Rayner and colleagues (Rayner, 1978; Rayner McConkie, & Ehrlich, 1978; Rayner, McConkie, & Zola, 1980). They have shown that a word or letter string appearing in parafoveal vision can facilitate the processing of a visually similar word appearing shortly afterwards in the fovea. Although their experimental paradigm differs somewhat from that used here, the two sets of experiments reach essentially the same conclusion; information acquired about a word in one retinal region can influence the perception of a word in another region. Rayner, McConkie, and Zola (1980) proposed that this information consists of the identities of the beginning letters of a word, though they did point out that additional information must be acquired when words are near the fovea (as they were in the present experiments).

Overall, the interactions they observed seem similar in nature to those of the present experiments, with the exception that they found no measurable interaction unless the foveal and parafoveal words shared at least the first letter in common. Nonetheless, Rayner, Well, Pollatsek, and Bertera (1982) have proposed an activation framework to account for their interactions that is much like the one I suggested for letter migrations. If the mechanisms underlying the two sorts of interactions are indeed similar, models of multiple-word perception should be capable of accounting for the integration of information across fixations as well as the letter-migration phenomenon.

The role of focal attention in word perception. The experiments reported here reveal structural limitations in the word-recognition system that restrict the number of words that can be perceived accurately and in parallel across the retina. Because of these limitations, preattentive-

processing mechanisms cannot always be trusted to register multiple words correctly. However, Experiment 2 showed that focusing attention on one word in the display can lower the migration rate to that word. Focal attention appears to prevent interference from the unattended word, perhaps by limiting activation of the unattended word or by raising the relative activation of the attended word, effectively limiting the number of words entering the processing system at once (see also Posner & Snyder, 1975; Rayner, McConkie, & Ehrlich, 1978, Experiment 3). This role of focal attention in word perception is distinct from but not incompatible with the role suggested by feature-integration theory, that of binding identified words to their spatial locations.

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